The microtremor experiment was conducted by Chevron Resources Co. in August 1978, at a site about a half mile northeast of exploration well Ginn 1-13, (Figure 4). The test site was occupied by a 120-element cross array, with 2000 ft diameter (Figure 5). Data were recorded with a 120-channel DFS V system.

The microtremors at the Beowawe test site are consistently dominated by 2 to 10 Hz coherent seismic noise (Figure 5). The results of *f-k* analyis reveal that the predominant coherent microtremors propagate through the test site with azimuths ranging from 225 and 333 degrees. The apparent velocities of 2, 3, and 4 Hz components range from 10,000 to 20,000 ft/sec across the geophone array. On the other hand, the 10 Hz components propagate with apparent velocities from 15,000 to 69,000 ft/sec. Figure 6 shows a typical contour plot of two-dimensional wavenumber power spectral density for a 4 Hz microtremor coming from 245 degree azimuth with 17,600 ft/sec velocity. Azimuthal angles for incoming microtremors do not correlate with any surface geothermal manifestation. The extremely high apparent velocity indicates that the detected microtremors are largely body wave components emanating from the buried sources.

Conclusions

The sources of the intermittent 2 Hz component microtremor in the Roosevelt area are not clear. One thing is definite: it does not originate from the existing geothermal system. The *f-k* analysis with array used in this study should have been sufficient to detect body waves emanating from the geothermal reservoir. We conclude that the geothermal reservoir at Roosevelt either (a) does not produce any microtremor event, or (b) it produces one that is too small to be detected by the *f-k* method. The low frequency microtremors detected in Beowawe geothermal area do not correlate with surface manifestation. The high apparent velocity body wave components imply that those microtremors are emanating from the buried sources at depth.

Acknowledgments

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Deep Electromagnetic Sounding in Central Nevada — GE.6

M. Wilt, N. E. Goldstein, J. R. Haught, and H. F. Morrison, Lawrence Berkeley Lab

Sixteen shallow and deep controlled source electromagnetic soundings were performed in Buena Vista Valley, near Winnemucca, Nevada, to investigate an intrabasement conductor previously detected with magnetotellurics. The survey was carried out with the LBL EM-60 system using a remote magnetic reference for low-frequency geomagnetic noise cancellation, 100 m and 2.8 km diameter transmitter loops, and a minicomputer for in-field processing. EM soundings were made at distances from 0.5 to 30 km from three loops over the frequency range 0.02 to 500 Hz. Data were interpreted by means of 1-D inversions and the resulting layered models were pieced together to yield an approximate 2-D geoelectric model along the north-south axis of the valley. The EM soundings and one MT sounding show a 3 to 7 Ω-m zone at a depth of 4 to 7 km. The conductor appears to be deepest at the northern end of the valley and shallowest beneath a basement ridge that seems to divide Buena Vista Valley into two basinal structures. Similar intrabasement conductors are also reported 50-75 miles south in the Carson Sink-Fallon areas, suggesting a common source, probably related to an anomalously hot, thin crust.

During the Spring of 1981 a deep electromagnetic sounding survey was undertaken by Lawrence Berkeley Laboratory (LBL) in Buena Vista Valley, Nevada to confirm the presence of a relatively shallow intrabasement conductor, first detected with magnetotelluric measurements, and to delineate the conductor by means of the LBL controlled-source system, modified for deep sounding work. Shallow crustal conductors have been reported at various places within the Basin and Range province and they are presumed related to the heat source that causes numerous hot springs, high regional heat flow, and widespread epithermal gold and mercury mineralization.

Sixteen controlled-source electromagnetic soundings and one magnetotelluric sounding were made in Buena Vista Valley, Pershing County, Nevada (Figure 1). The EM soundings were made relative to three loop sources with source-receiver separations ranging from 0.5 to 30 km. Two of the loops were four-turns and 100 m in diameter, similar to those we used previously for investigations to depths of about 2 km. The other was a 6.25 km^2, single-turn large-moment source capable of providing signal for deeper exploration. This large-diameter source had a moment of 2 $\times$ 10^8 mks, approximately 80 times greater than the smaller loops.

Features of the system, shown schematically in Figure 2, include an 8-channel multiplexer, a 2-channel digital oscilloscope for digitization, storage and display, and an HP 9835 minicomputer for data processing. Phase reference between loop current and observed magnetic fields was maintained by means of oven-controlled quartz clocks.

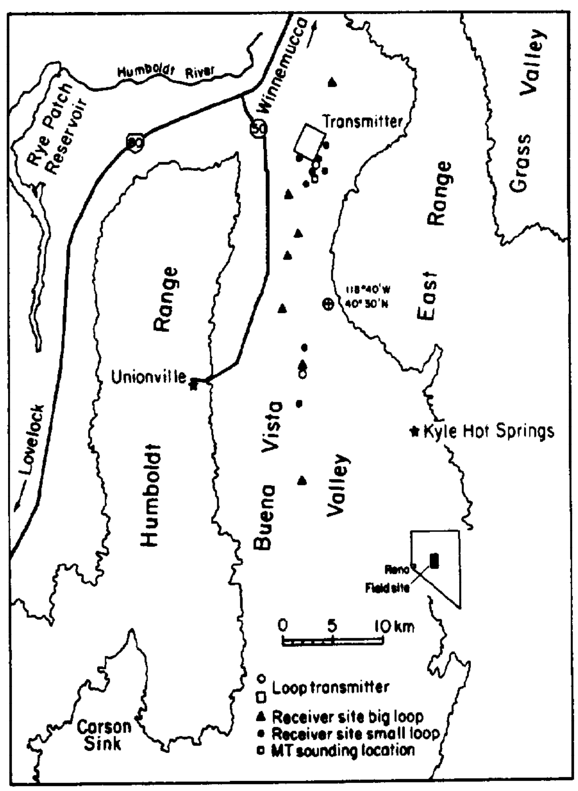

FIG. 1. Location map of the deep electromagnetic soundings, Buena Vista Valley, Pershing County, Nevada.

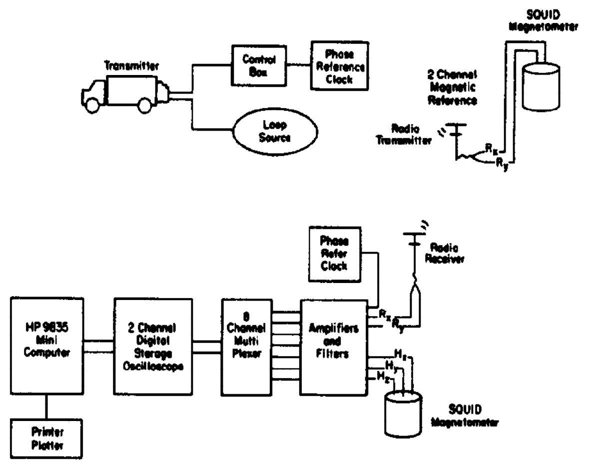

FIG. 2. Schematic diagram of the EM-60 controlled-source EM system.

A remote reference magnetometer, shown in the upper right corner of Figure 2, was used for noise cancellation during both the MT and controlled-source EM surveys. The MT noise cancellation technique was described by Gamble et al (1979). In the controlled-source work, a distant reference magnetometer provides signals to buck-out the natural geomagnetic variations at the receiver station. Our experience shows that a simple procedure of analog scalar subtraction performed with the transmitter off will reduce the geomagnetic "noise" by about 20 dB, thereby extending the useful frequency range down to ~0.02 Hz. The more elegant noise cancellation technique based on finding the tensor coefficients did not work as well because of the large amount of time needed to obtain the coefficients, and the instability of the coefficients over longer time intervals.

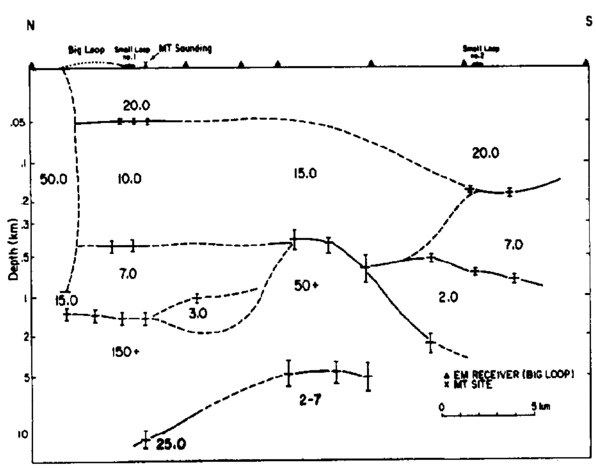

FIG. 3. Geoelectric cross-section showing interpreted resistivities along the axis of Buena Vista Valley, Pershing County, Nevada. Error bars are the standard error for the layer thickness.

Results

We performed 1-D inversions on all 16 EM soundings and the one MT sounding. The data for most stations fitted well to 1-D models, and these layered models were reasonably consistent from station to station (Figure 3).

The low resistivity (10-20 Ω-m) of the upper km presents some problems for deep electromagnetic sounding. Although signals could be received at up to 30 km from the source, the higher frequencies were severely attenuated by the conductive surface layer, making it impossible for us to get useable data above about 5 Hz when source-receiver separations exceeded 15 km. The low resistivity surface also limited penetration of EM waves, thus making low frequency data collection mandatory. Without noise cancellation, collection at low frequency data would have been very difficult.

Figure 3 is a composite of 1-D interpretations along a north-south line paralleling the valley. According to our convention, the layered-model interpretation is plotted at a point midway between the transmitter and the receiver. The resistivity cross-section reveals that the shallow portion of the crust beneath Buena Vista Valley can be approximated by 4 or 5 layers. The parameters of the top layer are resistivity of 20 Ω-m and a thickness of between 50 and 200 m. These parameters seem to be fairly consistent at most locations in the valley. This layer most likely represents partially saturated Quaternary alluvium. The second layer is some 200 to 500 m thick and approximately 10 Ω-m in resistivity. This unit is thickest in the northern and southern parts of the valley and may be absent in the center of the valley; it likely represents saturated Tertiary sediments and volcanics. Deeper parts of the section indicate conductive sediments overlying resistive basement. Basement depth ranges from 0.5 to 2.5 km with a basement high which suggests that the valley may be subdivided structurally into two basins, a northern one 1 to 1.5 km deep and a southern one 2 to 2.5 km deep. The resistivity of the basement is poorly resolved with EM and MT soundings because it carries relatively little current and therefore does not contribute greatly to the received signals.

Evidence for a conductor within the basement was found on three EM soundings and the MT sounding. For the EM soundings, a good electrical conductor (3 to 7 Ω-m) was indicated 4 to 7 km beneath the central portion of the valley. The MT sounding indicated a good conductor (approximately 25 Ω-m) 11 km in depth beneath the northern end of the valley. Fifty to 75 miles to the south in the Carson Sink, experiments by Keller et al (1981) and by the U.S.G.S. (Stanley et al, 1976) have indicated conductors at about 5 km in depth. It is tempting, therefore, to speculate on whether the conductors are related geologically, constituting a regional feature. On the basis of geothermal evidence, Stanley et al (1979) proposed that the conductor is caused by Tertiary and pre-Tertiary marine sediments saturated with water at 150° C or greater and with salinities of about 20,000 ppm. The widespread occurrence of the conductor seems to confirm that a broad area of the shallow crust is anomalously hot.

Although there are other surveys supporting the intrabasement conductor, our subsurface electrical model is only preliminary. The irregular valley shape, variable basement depth, and the anomalously small radial fields and large tangential fields observed suggest 3-D complexities. 2-D modeling suggests that the depth to the conductor may be underestimated in the 1-D inversions.

Acknowledgment

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Depth to Curie Isotherm in Arizona by Magnetic Anomaly Inversion GE.7

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Modeling sources of magnetic anomalies as variable magnetic layers with lateral susceptibility changes allow the depth to the Curie isotherm to be interpreted. If the Curie temperature isotherm depths are mapped, information as to the present thermal condition of the crust is obtained. A Backus-Gilbert method is used to solve for the lower boundary of 2-D bodies (models) which cause magnetic anomalies and to assess vertical accuracy (variance) and lateral resolution (spread). The lower boundary can be considered a continuous function. A depth to Curie isotherm map of Arizona is obtained from analysis of the state aeromagnetic map. Results are compared to other Curie depth studies as well as available geologic and geophysical data. The results agree in general with Curie depth investigations which employed spectral matching, but not with other types of magnetic anomaly analyses. Shallow depths (5–9 km below sea level) are indicated along the transition between the Colorado plateau and the Basin and Range provinces, in the White Mountains in east-central Arizona, in southwest Arizona, and in the Tucson area of southeast Arizona. Curie depths in central and south-central Arizona are 20 km below sea level which is unexpectedly deep for the Basin and Range. The results can be an aid in determining geothermal potential of the area when used in an integrated analysis.

Estimates of the thickness of the magnetized portion of the earth's crust suggest that magnetization boundaries can correspond to changes in composition within the crust or higher temperatures at depth which cause the rocks to lose their magnetism (the depth to Curie isotherm). It may be possible to locate a point on the isothermal surface by determining the depth at which the rock is no longer magnetic. If a sufficient number of Curie depths are obtained in an area, an isothermal surface at the Curie temperature would be defined and temperatures at other depths could be determined.

The general linear geophysical problem relates observation data with the unknown function and its defining kernels through an integral transform equation. A solution is estimated by the method suggested by Backus and Gilbert (1970). The quality of the solution can be expressed by the trade-off of spread versus variance and the average solution for the model. This approach is used for inversion of magnetic anomalies, being applied directly to the observed magnetic data with no manipulation of the data, such as reduction-to-pole processing. A known variable upper boundary of the magnetic body can be used to take into account magnetic terrain effects and different magnetic survey parameters. Lateral susceptibility contrast variations can be incorporated so that adjacent body interference can be considered.

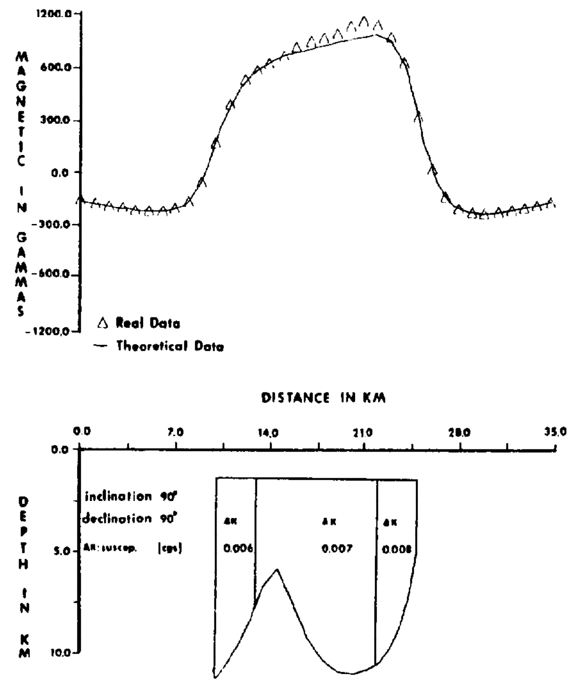

FIG. 1. Inversion of magnetic anomaly of synthetic model with incorrect assumption

Synthetic data were calculated for models and then inverted to determine the lower boundary solution. In Figure 1, boundaries and values of the lateral susceptibility contrasts were incorrectly placed. The fit between synthetic noise-free data and computed magnetic effects is considered insufficient. A change of susceptibility contrasts and block widths is considered necessary by the radical thinning of the lower boundary.

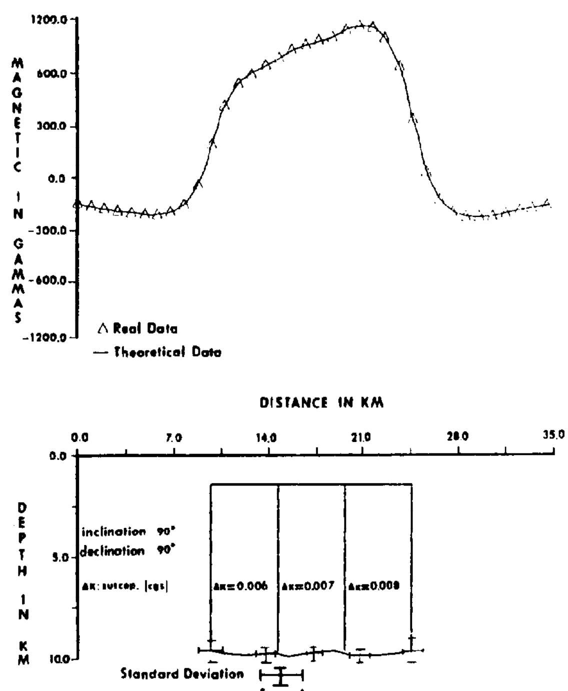

FIG. 2. Inversion of magnetic anomaly of synthetic model with correct assumption